TITLE OF THE INVENTION

VEHICLE-USE BEARING APPARATUS

This is a Continuation of Application No. 10/057,051 filed October 26, 2001.

BACKGROUND OF THE INVENTION

The present invention relates to a vehicle-use bearing apparatus of a disk rotor in a disk brake apparatus, a hub unit to which wheels are attached, and the like. Particularly the invention relates to the vehicle-use bearing apparatus having a double row tapered roller bearing with vertex of contact angles outside of bearing.

A double row tapered roller bearing with vertex of contact angles outside of the bearing is generally used to receive large radial load, axial load and moment load which are applied from a vehicle body of large weight.

In a vehicle-use bearing apparatus having such a bearing, the bearing is externally fitted to an outer periphery of a hub wheel to which wheels are attached, and a shaft portion end of the hub wheel is deformed outwardly in a radial direction so as to be caulked to an outer end surface of one inner ring of the bearing.

In order to maintain rolling performance on rolling contact surfaces of inner and outer rings of the tapered roller, as shown in Fig. 7 which is an enlarged diagram of a main section on the caulked side of the bearing, the bearing is designed so that extended lines along rolling contact surfaces 23a and 21a of the inner ring 23 and the outer ring 21 with respect to a rotational axis L of a shaft portion of the hub wheel

and an extended line along an outer peripheral surface of the tapered roller 22 meet at one point Q on the rotational axis L of the hub wheel.

In this case, $\theta 1$ is an angle of a raceway track of the inner ring 23 with respect to the rotational axis L, $\theta 2$ is an angle of a raceway track of the outer ring 21 with respect to the rotational axis L, and $\theta 3$ is an angle of an inner wall surface 23c of a cone back face rib 23b which is expanded outwardly in the radial direction on a large diameter side of the inner ring 23. The numeral 3 designates a section which is caulked by the shaft end of the hub wheel.

As to the angles of the raceway tracks $\theta 1$ and $\theta 2$ and the angle of the inner wall surface $\theta 3$, the same design is applied to the other inner ring and outer ring, not shown, and these angles correspond to the angles of the raceway tracks of the other inner and outer rings and the angle of the inner wall surface of the cone back face rib.

In the prior art, when the shaft end of the hub wheel is bent and deformed outwardly in the radial direction so as to be caulked to the outer end surface of the inner ring 23, since the rolling contact surfaces 23a and 21a of the inner and outer rings and the cone back face rib 23b are elastically deformed, the angles of the raceway tracks $\theta 1$ and $\theta 2$ and the angle of the inner wall surface 23c, $\theta 3$, which are regulated to originally required angles are occasionally changed.

In this case, a contact state of the tapered roller with the rolling contact surfaces and the inner wall surface becomes unstable, namely, a life of the bearing apparatus is influenced.

SUMMARY OF THE INVENTION

Therefore, it is a main object of the present invention to provide a vehicle-use bearing apparatus in which, after a shaft end of a hub wheel is caulked, forms of raceway tracks of inner and outer rings are optimized and a life of a bearing can be improved.

Other objects, characteristics and advantages of the present invention will become clear by the following description.

Briefly stated, the present invention includes: a hub wheel to which a wheel is attached; and a double row tapered roller bearing with vertex of contact angles outside of the bearing to be attached to an outer periphery of said hub wheel, designed so that a shaft end of the hub wheel is deformed outwardly in a radial direction so as to be caulked to an outer end surface of an inner ring of the tapered roller bearing, and the tapered roller bearing has an inner ring and an outer ring whose rolling contact surfaces are tapered and a tapered roller which is arranged between the rolling contact surface of the inner ring and the rolling contact surface

of the outer ring, and a form of a raceway track of at least one of the inner and outer rings is designed so as to satisfy a condition that a predetermined form is secured in a state that the raceway track is elastically deformed by the caulking.

In this design, even if the shaft end of the hub wheel is bent and deformed outwardly in the radial direction to the outer end surface of the inner ring so as to be caulked, an angle of the raceway tracks of the inner and outer rings after caulking, for example, an angle of the rolling contact surfaces of the inner and outer rings can be set to a prescribed angle which is originally required. As a result, in accordance with this design, satisfactory rolling performance of the tapered roller can be secured, and these raceway tracks and raceway tracks of the other inner and outer rings can be balanced. A predetermined life of the bearing apparatus after the caulking can therefore be obtained.

Preferably in accordance with embodiment of the present invention, the condition is such that the form of the raceway track of at least one of the inner and outer rings before caulking is set so that an extended line along one of the rolling contact surface and an extended line along an outer peripheral surface of the tapered roller meet at a rotational axis of the hub wheel after the caulking.

Preferably in accordance with a further embodiment of the present invention, the condition is such that the forms of the raceway tracks of the inner and outer rings before the caulking are set so that extended lines along the rolling contact surfaces

of the outer and inner rings and an extended line along an outer peripheral surface of the tapered roller meet at a rotational axis of the hub wheel.

In accordance with a further embodiment of the present invention, preferably the condition is such that an angle of the rolling contact surface of the inner ring before the caulking is set to an angle obtained by subtracting a fluctuation angle of the rolling contact surface due to the caulking from an angle of the rolling contact surface where the raceway track of the inner ring secures a required form.

In accordance with yet another embodiment, preferably the condition is such that an angle of the rolling contact surface of the outer ring before the caulking is set to an angle obtained by adding a fluctuation angle of the rolling contact surface of the inner ring due to the caulking to an angle of the rolling contact surface where the raceway track of the outer ring secures a required form.

These and other objects, as well as advantages of the invention, will become clear by the following description of preferred embodiments of the invention with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of a longitudinal section of a vehicle-use bearing apparatus according to an embodiment of the present invention;

Fig. 2 is an enlarged diagram of a main section of Fig. 1;

Fig. 3 is a function explanatory diagram of the vehicle-use bearing apparatus of Fig. 1;

Fig. 4 is an another function explanatory diagram of the vehicle-use bearing apparatus of Fig. 1;

Fig. 5 is a side diagram of a longitudinal section of the vehicle-use bearing apparatus according to another embodiment of the present invention;

Fig. 6 is a side view of a longitudinal section of the vehicle-use bearing apparatus according to still another embodiment of the present invention; and

Fig. 7 is an enlarged cross section of a main section of a prior vehicle-use bearing apparatus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

There will be explained below a vehicle-use bearing apparatus of the present invention which is applied to an automobile. This bearing apparatus is not limited to an automobile use, and can be applied similarly to other vehicles, such as a railway vehicle.

With reference to Figs. 1 through 3, a symbol A shows a whole vehicle-use bearing apparatus which is used on a driven wheel of an automobile.

A hub wheel 1 has an annular flange 11 which faces outwardly in a radial direction, to which a wheel, not shown, is attached, on a vehicle outer side. A double row tapered roller bearing with vertex of contact angles outside of bearing 2 is externally fitted to an outer periphery of a vehicle inner side of the hub wheel 1.

This bearing 2 includes a single outer ring 21 having two-row rolling contact surfaces 21a and 21b adjacent to each other in an axial direction, a plurality of tapered rollers 22 which are arranged on the two-row rolling contact surfaces 21a and 21b, and an inner ring 23 which has a single rolling contact surface 23a which is paired with the rolling contact surface 21a on the vehicle inner side of the outer ring 21 and is fitted to an outer peripheral surface of the hub wheel 1. Moreover, the bearing 2 is constituted so that a required area of the outer peripheral surface of the hub wheel 1 is utilized as a rolling contact surface 12a which is paired with the rolling contact surface 21b on the vehicle outer side of the outer ring 21. The numeral 25 designates a cage.

The rolling contact surface 21a on the vehicle inner side of the outer ring 21 is tapered such that its diameter is larger towards a shaft end of the vehicle inner side of the hub wheel 1. The rolling contact surface 21b of the vehicle outer side is

tapered such that its diameter is larger towards a shaft end of the vehicle outer side of the hub wheel 1.

The rolling contact surface 23a of the inner ring 23 is tapered such that its diameter is larger towards the shaft end of the vehicle inner side of the hub wheel 1. A cone back face rib 23b which is expanded outwardly in the radial direction is formed on the large diameter side of the tapered rolling contact surface 23a.

A raceway track of the inner ring 23 is composed of the tapered rolling contact surface 23a and an inner wall surface 23c of the cone back face rib 23b.

The vehicle inner side of the hub wheel 1 has a hollow form, and the shaft end of the vehicle inner side is bent outwardly in the radial direction and is caulked to an outer end surface of the inner ring 23 of the bearing 2 so as to be a caulked portion 3.

A radially outward flange 24 is provided on an outer periphery of the outer ring 21. The outer ring 21 is mounted to an axle case or the like, not shown, via the flange 24 so as to be non-rotatable.

The raceway tracks of the inner ring 23 and the outer ring 21 in the bearing 2 are designed so as to satisfy a condition which secures a predetermined form in a state that the raceway tracks are elastically deformed by caulking.

This design approach will be explained below with reference to Fig. 3. Fig. 3 shows an exaggerated state to simplify understanding.

Briefly stated, the inner ring 23, the outer ring 21 and the inner wall surface 23c are designed so that the raceway tracks of the inner ring 23, the outer ring 21 and the inner wall surface 23c of the cone back face rib 23b have predetermined forms before caulking (forms shown by virtual lines) which are different from the forms shown by continuous lines in order to allow elastic deformation due to caulking for the originally required forms (forms shown by the continuous lines).

In order to obtain this design form, a change amount according to a caulking load for each dimension of the vehicle-use bearing apparatus is checked by experiment, and the design is obtained experimentally so as to be set.

The details will be explained below. Firstly θ1a, θ2a and θ3a are angles of the shaft end of the hub wheel 1 before caulking, and the raceway tracks of the inner ring 23 and the outer ring 21 are designed so as to obtain forms based on these angles before caulking.

In addition, θ1, θ2 and θ3 are angles after caulking, and angles which obtain the originally required forms of the raceway tracks of the inner ring 23 and the outer ring 21.

Here, θ1a and θ1 are angles of the rolling contact surface of the inner ring 23 with respect to a rotational axis L of the hub wheel 1, θ2a and θ2 are angles of the rolling contact surface of the outer ring 21 with respect to the rotational axis L of

the hub wheel 1, and $\theta 3a$ and $\theta 3$ are tilt angles of the inner wall surface 23c of the cone back face rib 23b with respect to the radial direction.

As a result of the experiment, the angle of the rolling contact surface of the inner ring 23 before caulking becomes larger after caulking, namely, it is changed from $\theta 1a$ to $\theta 1$, and the angle of the rolling contact surface of the outer ring 21 before caulking does not change after caulking ($\theta 2a = \theta 2$).

The tilt angle of the inner wall surface 23c of the cone back face rib 23 before caulking becomes smaller after caulking, namely, it is changed from $\theta 3a$ to $\theta 3$.

The tilt angle of the inner wall surface 23c of the cone back face rib 23 becomes smaller due to caulking, namely, it is changed from $\theta 3a$ to $\theta 3$ because the angle of the rolling contact surface of the inner ring 23, $\theta 1a$, before caulking becomes larger due to caulking and becomes $\theta 1$ after caulking, and the angle of the rolling contact surface of the outer ring 21, $\theta 2a$ does not change before and after caulking and thus the tapered rollers 22 pushes the cone back face rib 23 due to a wedge effect.

Fluctuating angles of the inner ring 23, the outer ring 21 and the inner wall surface 23c which fluctuate due to a caulking load with respect to the outer end surface of the inner ring 23 due to caulking are $\Delta\theta 1$, $\Delta\theta 2$ and $\Delta\theta 3$.

The angle of the rolling contact surface of the inner ring 23 before caulking $\theta 1a$ is set to an angle $\theta 1a$ (= $\theta 1 - \Delta\theta 1$) obtained by subtracting a fluctuation angle

of the rolling contact surface $\Delta\theta 1$ from the angle of the rolling contact surface $\theta 1$ where the raceway track of the inner ring 23 secures the originally required form.

The tilt angle $\theta 3a$ of the inner wall surface 23c of the cone back face rib 23 before caulking is set to an angle $\theta 3a$ (= $\theta 3 + \Delta\theta 3$) obtained by adding a fluctuation tilt angle $\Delta\theta 3$ due to caulking to the tilt angle $\theta 3$ where the inner wall surface 23c secures the originally required form.

With the above settings, the angle of the rolling contact surface of the inner ring 23 is changed from $\theta 1a$ before caulking into $\theta 1$ after caulking, and the tilt angle of the inner wall surface 23c is changed from $\theta 3a$ before caulking into $\theta 3$ after caulking.

As a result, as shown in Fig. 3, after caulking, extended lines L1 and L2 along the rolling contact surfaces of the inner ring 23 and the outer ring 21 and an extended line along the outer peripheral surface of the tapered rollers 22 with respect to the rotational axis L of the hub wheel 1 meet at one point Q on the rotational axis L. The forms of the rolling contact surfaces of the inner ring 23 and the outer ring 21 and the inner wall surface 23c are optimized, and their contact states with the tapered rollers 22 become stable so that the life of the bearing is improved.

In the case of the above embodiment, elastic deformation due to caulking is allowed for the originally required forms (forms shown by continuous lines) of the angle of the rolling contact surface, $\theta 1a$, of the inner ring 23 and the tilt angle $\theta 3a$

of the inner wall surface 23c, and thus the angle of the rolling contact surface, $\theta 1a$, of the inner ring 23 and the tilt angle $\theta 3a$ of the inner wall surface 23c are designed so as to have predetermined forms (shown by virtual lines) different from the forms shown by continuous lines before caulking. However, the raceway track of the outer ring 21 can be designed in such a manner.

In the case where the raceway track of the outer ring 21 is so designed, as shown in Fig. 4, the angle of the rolling contact surface of the inner ring 23 is fixed to $\theta 1$, and the angle of the rolling contact surface of the outer ring 21 is intentionally set to an angle $\theta 2a'$ ($= \theta 2 + \Delta\theta 1$) obtained by adding a fluctuation angle of the rolling contact surface of the inner ring 23, $\Delta\theta 1$, to the angle of the rolling contact surface, $\theta 2$, where the raceway track of the outer ring 21 secures the originally required form. As a result, deformation due to the angle of the rolling contact surface of the inner ring 23 can be absorbed by the side of the outer ring 21.

In addition, since $\Delta\theta 3$ is obtained because $\theta 2a = \theta 2$ due to $\Delta\theta 1$, $\Delta\theta 3 \fallingdotseq 0$ due to $\theta 2a'$.

Further, the above design can be applied to the forms of the raceway tracks of both the inner ring 23 and the outer ring 21. In this case, a fluctuation angle of the rolling contact surface of the inner ring 23, $\Delta\theta 1$, due to caulking is allocated to the angles of the rolling contact surfaces of the inner ring 23 and the outer ring 21.

Here, in the above embodiment, one of the two inner rings in the tapered roller bearing 2 is the inner ring 23 itself, but as for the other inner ring, the required area of the outer peripheral surface of the hub wheel 1 is utilized as the rolling contact surface 12a which is pared with the rolling contact surface 21a on the vehicle outer side of the outer ring 21.

Alternatively, the present invention can be applied to a structure that both the inner rings 23 in the tapered roller bearing 2 shown in Fig. 5 are provided to the vehicle outer side and the vehicle inner side.

Namely, also in the case of the vehicle-use bearing apparatus of Fig. 5, the raceway track of at least one of the outer ring 21 and the vehicle inner side inner ring 23 in the tapered bearing 2 is desired so as to satisfy a condition that a predetermined form is secured in a state that the raceway track is elastically deformed by the caulking. This condition can be also determined similarly to the embodiments in Figs. 1 through 3.

Here, the vehicle-use bearing apparatus in the above embodiment is on the driven wheel side of the vehicle, but may be on the driving wheel side as shown in Fig. 6.

The vehicle-use bearing apparatus shown in Fig. 6 has an equal velocity joint 3 in addition to the hub wheel 1 and the double row tapered roller bearing with vertex of contact angles outside of bearing 2.

The hub wheel 1 has a center hole 1a.

The equal velocity joint 3 is called, for example, as a well-know Zeppa type (bar field type) equal velocity joint, and it is composed of an outer ring 31, an inner ring 32, a ball 33, a cage 34 and the like.

The outer ring 31 is composed of a bowl type drum section 35 which houses the inner ring 32, ball 33, the cage 34 and the like, and a shaft section 36 which is connected integrally with a small diameter side of the bowl type drum section 35.

One end of a shaft 7 (driving shaft) is spline-fitted into the inner ring 32 and is fixed by a retaining ring (symbol not shown) so as not to slip off, and the other end of the shaft 7 is attached to a vehicle differential device via another equal velocity joint, not shown.

The double row tapered roller bearing with vertex of contact angles outside of bearing 2 is attached to the outer peripheral surface of the hub wheel 1, and the equal velocity joint 3 is attached to the center hole 1a of the hub wheel 1 so as to be rotatable integrally with the hub wheel 1 in a state that it is close to the double row tapered roller bearing with vertex of contact angles outside of bearing 2.

In addition, a bolt 13 for fixing a disc rotor and a wheel (not shown) of a disc brake apparatus is attached to some places on the circumference of the flange 11 in a penetrative state.

In such a vehicle-use hub unit, a rotational power of the shaft 7 is transmitted to the wheel (not shown) attached to the hub wheel 1 via the equal velocity joint 3.

Also in the case of the embodiment of Fig. 6, the double row tapered roller bearing with vertex of contact angles outside of bearing 2 is designed so as to satisfy a condition that a predetermined form is secured in a state that the raceway tracks of the inner ring 23 and the outer ring 21 are elastically deformed by caulking. The condition can be determined similarly to the embodiments in Figs. 1 through 3.

While there has been described what is at present considered to be preferred embodiments of this invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of this invention.